Unit 7
Evolution
Chapter 19: Descent with Modification

Who Influenced Darwin?

- **Evolution** can be defined by Darwin's phrase *descent with modification*
  - Change over time

- Carolus Linnaeus was the founder of taxonomy
  - The branch of biology concerned with classifying organisms
- He developed the binomial format for naming species (for example, *Homo sapiens*)

- Georges Cuvier studied fossils (paleontology)
  - He noted that the older the stratum (layer of rock), the more dissimilar its fossils were to current life-forms
  - From one layer to the next, some new species appeared while others disappeared
  - He speculated that each boundary between strata represents a catastrophe that destroyed many species
- Geologists James Hutton and Charles Lyell perceived that changes in Earth's surface can result from slow, continuous actions still operating today
  - Earth is more than a few thousand years old

- Lamarck hypothesized that species evolve through
  - Use and disuse of body parts
  - Inheritance of acquired characteristics
- The mechanisms he proposed are unsupported by evidence!
  - Acquired traits CANNOT be inherited!
- But he did recognize that the match of organisms to their environments can be explained by gradual evolutionary change

Descent with Modification

- Darwin observed many examples of **adaptations**
  - Inherited characteristics that enhance their survival and reproduction in specific environments
- Darwin noted that humans have modified other species by selecting and breeding individuals with desired traits
  - Called **artificial selection**
  - Noted that a similar process occurs in nature
    - **Natural selection** is a process in which individuals with favorable inherited traits are more likely to survive and reproduce

- If certain heritable traits are advantageous, individuals with those traits will survive and reproduce at a higher rate
  - This will increase the frequency of individuals with these traits
  - Those traits will accumulate in a population over time
- This process explains the match between organisms and their environment

- Note that individuals do not evolve!
  - Populations evolve over time!
- Natural selection can only increase or decrease heritable traits that vary in a population
  - If all individuals in a population are genetically identical for a trait, evolution by natural selection cannot occur
- Adaptations vary with different environments

Evidence of Evolution

- New discoveries continue to fill the gaps identified by Darwin in *The Origin of Species*
- There are four types of data that document the pattern of evolution
    1. Direct Observations
        - Ex: Correlation between food and beak size
    2. Homology
        - Similarity resulting from common ancestry
    3. The Fossil Record
    4. Biogeography
        - Scientific study of the geographic distribution of species

- **Homologous structures**
  - Similar structure
  - Function may be different
  - Indicated common ancestor
  - Ex: Bones in forelimbs of various mammals
    - Molecular level: Genes shared among organisms with common ancestor
- **Analogous structures**
  - Similar function
  - Not common ancestry
  - Ex: Wings of bird vs insect
- **Vestigial structures** are remnants of features that served important functions in the organism's ancestors

- Note: **Convergent evolution** is the independent evolution of similar features in different lineages
  - Results in **analogous** traits
    - Similar features in distantly related groups
    - Share similar function but NOT common ancestry
  - Arise when groups independently adapt to similar environments in similar ways
- Convergent evolution does NOT provide information about ancestry

Unit 7
Evolution

Chapter 20: Phylogeny

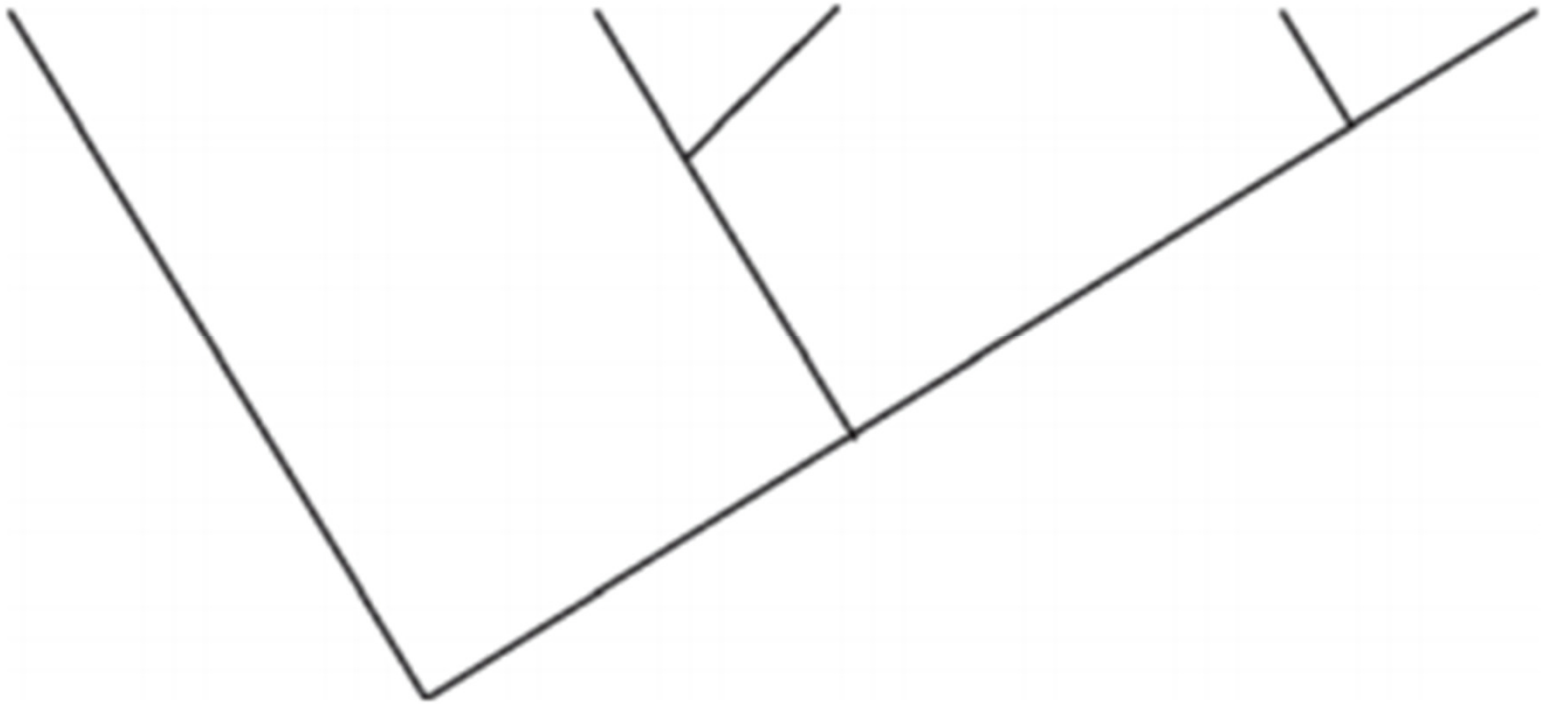
Phylogenetic Tree: Practice

The amino acid sequence of cytochrome c was determined for 5 different species of vertebrates. The table below shows the number of differences in the sequences between each pair of species.

THE NUMBER OF AMINO ACID DIFFERENCES IN CYTOCHROME *c* AMONG FIVE SPECIES

	E. ferus	*D. polylepis*	*G. gallus*	*A. forsteri*	*E. africanus*
E. ferus	0	21	11	13	1
D. polylepis		0	18	17	20
G. gallus			0	3	10
A. forsteri				0	12
E. africanus					0

- Using the data in the table, create a phylogenetic tree on the template provided to reflect the evolutionary relationships of the organisms. Provide reasoning for the placement on the tree of the species that is least related to the others.



Unit 7
Evolution

Chapter 21: The Evolution of Populations

Microevolution

- Natural selection acts on individuals, but only POPULATIONS evolve over time
- **Microevolution** is a change in allele frequencies in a population over generations
- Three mechanisms cause allele frequency change
  1. *Natural selection*: Eliminates members of a population that are least adapted
  2. *Genetic drift*: Chance events that alter allele frequencies
  3. *Gene flow*: Transfer of alleles between populations
- Only natural selection causes adaptive evolution

Genetic Variation

- Variation in heritable traits is a prerequisite for evolution
  - Diversity is essential!
- *Mutations* are the source of all genetic variation
  - Change in DNA sequence
- Sexual reproduction can shuffle existing alleles into new combinations through three mechanisms:
  - Crossing over
  - Independent assortment
  - Random Fertilization

Hardy-Weinberg

- The Hardy-Weinberg principle describes a population that is NOT evolving
- The five conditions for nonevolving populations are rarely met in nature
  1. No mutations
  2. Random mating
  3. No natural selection
  4. Extremely large population size
  5. No gene flow
- Departure from these conditions usually results in evolutionary change

$$p^2 + 2pq + q^2 = 1 \quad \text{and} \quad p + q = 1$$

- p represents the relative frequency of the dominant allele
- q represents the relative frequency of the recessive allele
- p^2 represents the frequency of the homozygous dominant genotype
- q^2 represents the frequency of the homozygous recessive genotype
- $2pq$ represents the frequency of the heterozygous genotype

Natural selection, Genetic drift, and Gene flow

Three major factors alter allele frequencies and bring about most evolutionary change

1. Natural selection
   - Individuals with traits that are better suited to the environment tend to produce more offspring than those with traits not as well suited
   - Only natural selection can cause adaptive evolution!
2. Genetic drift
3. Gene flow

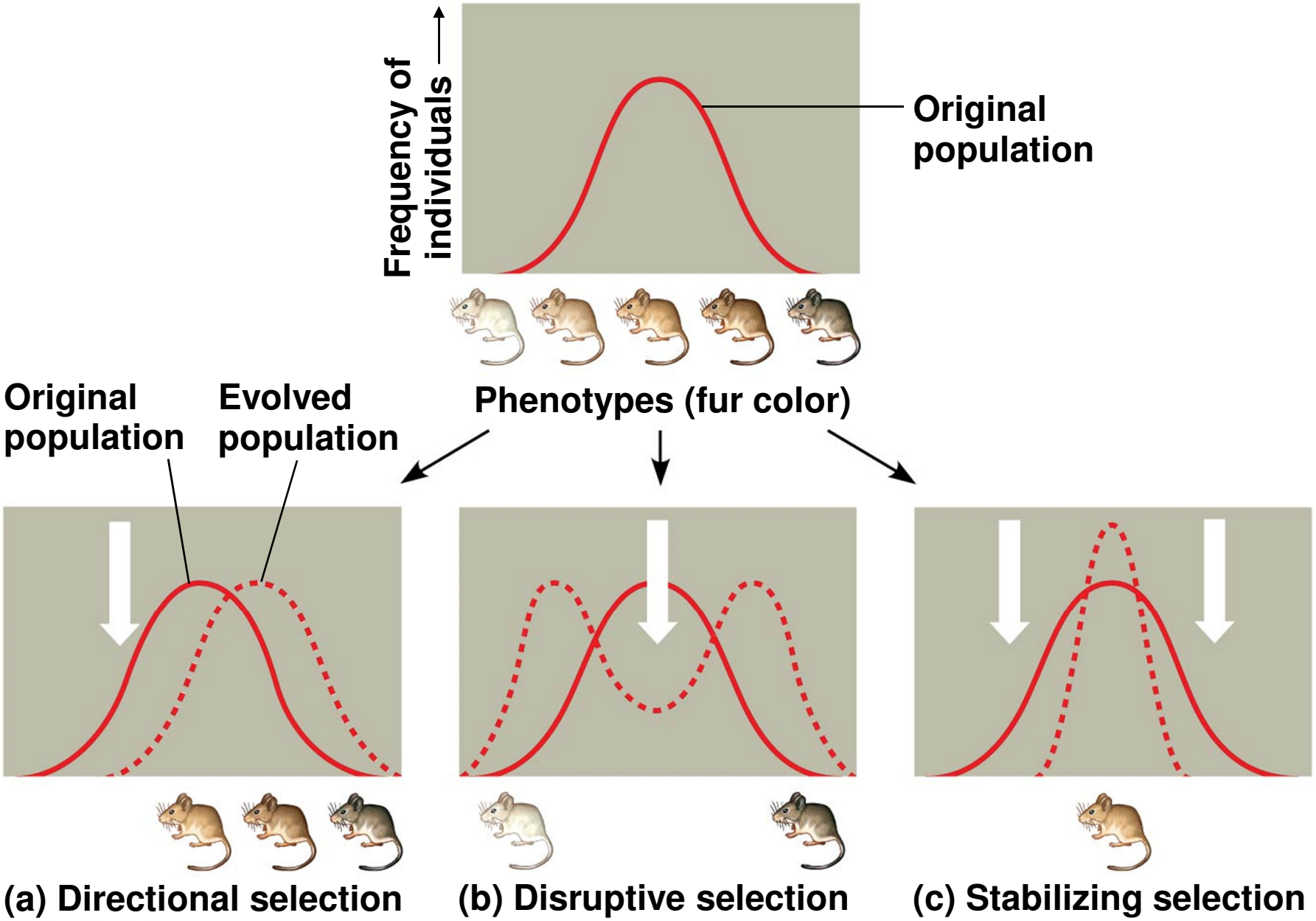
- **Genetic drift** describes how allele frequencies fluctuate unpredictably from one generation to the next due to chance events (random!)
  - Especially in small populations
- Genetic drift tends to reduce genetic variation through losses of alleles
- Two examples of how genetic drift can have a significant impact on a population are
  - The **founder effect**
    - Occurs when a few individuals become isolated from a larger population
  - The **bottleneck effect**
    - Results from drastic reduction in population size due to sudden environmental change

- **Gene flow** consists of the movement of alleles among populations
- Gene flow tends to reduce genetic variation among populations over time
  - Can result in two populations combining into a single population with a common gene pool

Directional, Disruptive, and Stabilizing Selection

- There are three modes of natural selection
  1. **Directional selection** favors individuals at one extreme of the phenotypic range
  2. **Disruptive selection** favors individuals at both extremes of the phenotypic range
  2. **Stabilizing selection** favors intermediate variants and acts against extreme phenotypes
     - Reduces variation
     - Ex: Birth weights of most human babies are between 6.6 and 8.8 lbs

Figure 21.13


Frequency of individuals
Original population
Phenotypes (fur color)
Original population
Evolved population
(a) Directional selection
(b) Disruptive selection
(c) Stabilizing selection

Sexual Selection

- **Sexual selection** is a form of natural selection in which individuals with certain inherited characteristics are more likely than others to obtain mates
- *Intrasexual selection* is competition among individuals of one sex (often males) for mates of the opposite sex
- *Intersexual selection*, often called mate choice, occurs when individuals of one sex (usually females) are choosy in selecting their mates
- Can result in **sexual dimorphism**
  - Marked differences between the sexes in secondary sexual characteristics

Unit 7
Evolution

Chapter 22: Origin of Species

Speciation

- **Speciation** is the process by which one species splits into two or more species
- According to the **biological species concept:**
  - A **species** is a group of populations whose members have the potential to interbreed in nature and produce viable, fertile offspring
  - They do not breed successfully with other populations
- The absence of gene flow plays a key role in the formation of new species!

Reproductive Isolation

- **Reproductive isolation** is the existence of biological barriers that impede two species from producing viable, fertile offspring
  - Blocks gene flow between species
  - Limits formation of **hybrids**
    - The offspring of crosses between different species
- Reproductive isolation can be classified by whether barriers act before or after fertilization

- **Prezygotic barriers** block fertilization from occurring by
  - **Habitat isolation**:
    - Two species rarely encounter each other because they occupy different habitats
  - **Temporal isolation**:
    - Species that breed at different times
  - **Behavioral isolation**:
    - Courtship rituals are unique
  - **Mechanical isolation**:
    - Morphological differences prevent successful mating
  - **Gametic isolation:**
    - Sperm of one species may not be able to fertilize eggs of another species

- **Postzygotic barriers** prevent the hybrid zygote from developing into a viable, fertile adult by
  - **Reduced hybrid viability**:
    - Hybrid does not develop properly and can't survive
  - **Reduced hybrid fertility**:
    - Hybrids are sterile
  - **Hybrid breakdown**:
    - Some first-generation hybrids are fertile, but next generation are feeble or sterile

Allopatric vs Sympatric Speciation

- **Allopatric speciation**
  - A population divides into different species because they become geographically isolated from each other
- **Sympatric speciation**
  - Speciation takes place in populations that live in the same geographic area
  - Less common than allopatric speciation
  - Occurs when gene flow is reduced between groups that remain in contact through factors including
    - Polyploidy
    - Habitat differentiation
    - Sexual selection

Speciation Rates

- Speciation begins only after gene flow between population is interrupted
- Once gene flow is interrupted, the populations must diverge genetically to the point where they become reproductively isolated
- The fossil record includes examples of species that appear suddenly, persist essentially unchanged for some time, and then apparently disappear
  - These periods of apparent stasis punctuated by sudden change are called **punctuated equilibria**
- The punctuated equilibrium model contrasts with a model of gradual change in a species' existence
- The interval between speciation events can range from 4,000 years to 40 million years, with an average of 6.5 million years

Unit 7
Evolution

Chapter 23: Broad Patterns of Evolution

The Fossil Record

- The fossil record is biased in favor of species that
  - Existed for a long time
  - Were abundant and widespread
  - Had hard shells, skeletons, etc.
- Sedimentary strata reveal the relative ages of fossils
- The absolute ages of fossils can be determined by **radiometric dating**
- Radiocarbon dating can be used to date fossils up to 75,000 years old
- For older fossils, some isotopes can be used to date volcanic rock layers above and below the fossil

Mass Extinctions

- The fossil record shows that most species that have ever lived are now extinct
- Extinction can be caused by changes to a species' environment
- At times, the rate of extinction has increased dramatically and caused a **mass extinction**
  - Mass extinction is the result of disruptive global environmental changes

- In each of the five mass extinction events, more than 50% of Earth's species became extinct
- A number of factors might have contributed to these extinctions
  - Intense volcanism
  - Global warming resulting from the emission of large amounts of CO_2 from the volcanoes
  - Reduced temperature gradient from equator to poles
  - Oceanic anoxia from reduced mixing of ocean waters
  - Meteorite and subsequent dust clouds

Adaptive Radiations

- Mass extinction can pave the way for adaptive radiations
- **Adaptive radiation** is the evolution of many diversely adapted species from a common ancestor
  - Many new species form whose adaptations allow them to fill different ecological roles (niches)
- Adaptive radiations may follow
  - Mass extinctions
  - The evolution of novel characteristics
  - The colonization of new regions
- Adaptive radiations can occur when organisms colonize new environments with little competition
  - Ex: Islands (Hawaii)